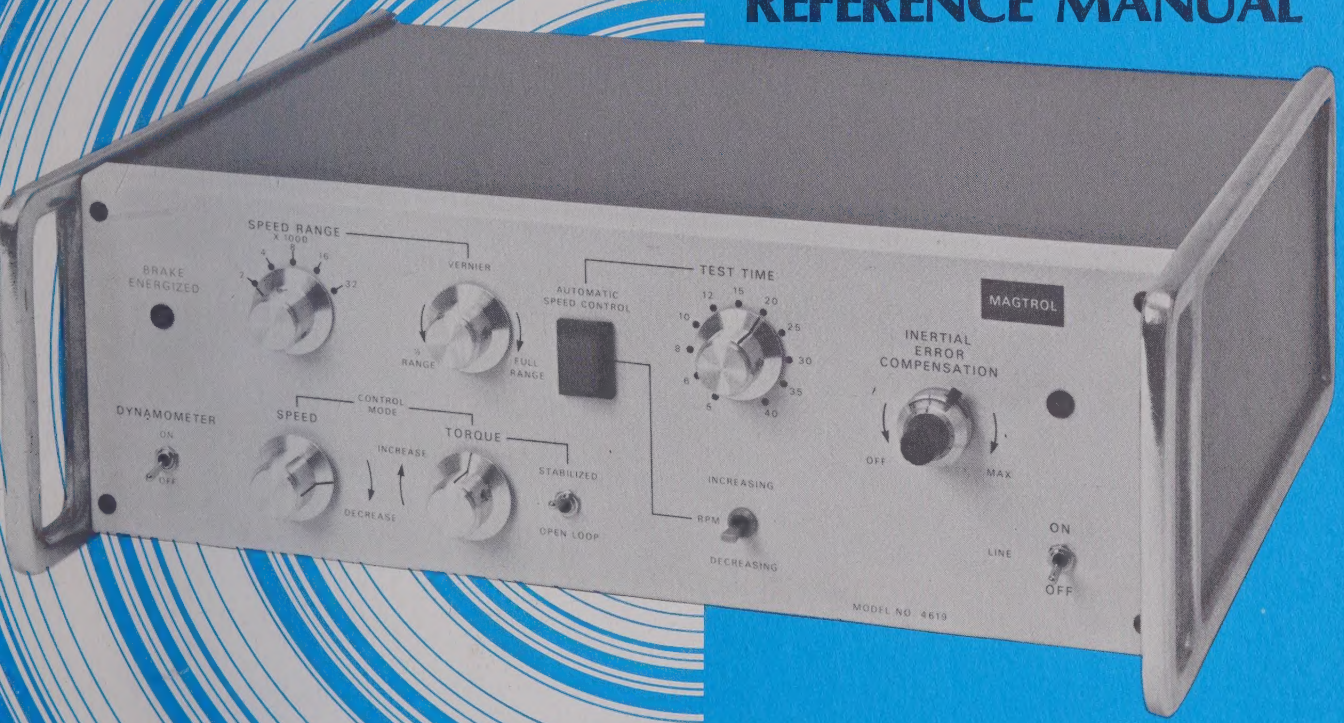
DYNAMOMETER/X-Y CONTROLLER
MODEL 4619

INSTRUCTION AND REFERENCE MANUAL



products for controlling
and measuring power

MAGTROL

FUNCTION IDENTIFICATION PHOTOS
OF CONTROLLER, READOUT, AND DYNAMOMETER
UNDER THIS FOLDOUT FLAP

MAGTROL
DYNAMOMETER/X-Y CONTROLLER

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OPERATING INSTRUCTIONS

SCHEMATIC REFERENCES

1.0 INTRODUCTION

1.1 UNPACKING All shipments leaving our plant are adequately packed and packaged. If there are signs of damage to this carton or its contents, please notify the shipper within 24 hours and retain carton and packing material for his examination.

1.2 FEATURES OF THIS MANUAL The foldout flap on the front cover contains annotated photos (Figure 1) of this Model 4619 dynamometer/XY controller and typical associated gear, showing connections and functions for both, also the connections on a typical Magtrol dynamometer. For convenient instant reference keep the flap opened out as you go through the connecting instructions (Section 2) and operational checkout (Section 3).

For additional convenience and faster identification, functions appearing on the panels of both controller and readout are shown throughout this manual in small capital letters.

2.0 CONNECTING INSTRUCTIONS

Three pieces of equipment must be interconnected for operation of this Model 4619 controller: a Magtrol digital dynamometer, a Model 4605 or 4615 readout, and the controller.

The Model 4619 controller will additionally provide torque and speed readouts to an X-Y recorder or other analog recording instruments. Information and instructions on this application are given in Sections 4 and 5.

To interconnect the three basic units proceed as follows:

2.1 Plug the dynamometer (cooling fan) line cord into the outlet provided on the rear panel of the readout.

2.2 Connect the 2-pin dynamometer brake cable (part number 88CS2) between the dynamometer and the controller.

2.3 Connect and lock the 14-pin cable (part number 88CS1) between the readout and the dynamometer.

2.4 Connect the BNC to the miniature plug (part number 88CS4) between the readout SPEED OUTPUT and the controller SPEED INPUT .

2.5 Connect the 4-pin miniature cable (part number 88CS3) between the readout TORQUE OUTPUT and the controller TORQUE INPUT .

You are now ready to proceed with equipment checkout and manual operation of the interconnected units.

3.0 OPERATIONAL CHECKOUT

Complete the motor fixturing so that motor and dynamometer shafts are aligned. The means of coupling the shafts should be angularly flexible and must be torsionally rigid. (Note: Torsionally flexible couplings (molded rubber, e.g.) should not be used; because of the high response of the Model 4619 controller they can induce system instability resulting in high-frequency shaft oscillation.)

3.1 Set the front-panel controls on the controller as follows:

3.1. 1 DYNAMOMETER ON/OFF switch to OFF.

3.1. 2 SPEED RANGE to the first value above the maximum anticipated free-run speed of the motor.

3.1. 3 SPEED RANGE VERNIER to full clockwise.

3.1. 4 SPEED (CONTROL MODE) to full counterclockwise.
TORQUE (CONTROL MODE) to full counterclockwise.

3.1. 5 STABILIZED/OPEN LOOP switch to OPEN LOOP.

3.1. 6 AUTOMATIC SPEED CONTROL to off (illuminating pushbutton unlit).

3.1. 7 TEST TIME to any desired setting.

3.1. 8 RPM INCREASING/DECREASING to its center neutral position opposite RPM.

3.1. 9 INERTIAL ERROR COMPENSATION to full counterclockwise (zero on both rotating scales).

3.1.10 LINE ON/OFF to ON.

3.2 Start the motor and check to be sure the free-run speed indicated by the tachometer is lower than the SPEED RANGE switch setting.

3.3 Switch the DYNAMOMETER ON/OFF toggle to ON.

3.4 Slowly rotate the SPEED RANGE VERNIER counterclockwise until the BRAKE ENERGIZED light goes on. Then rotate it very slightly until the light just goes out, and leave it at this setting. Note: If the motor speed is less than 1000 RPM, set the vernier at maximum counterclockwise (the BRAKE ENERGIZED light will not go on).

3.5 Slowly rotate the SPEED control clockwise. This causes the dynamometer to load the test motor and the BRAKE ENERGIZED light will go on; continuing clockwise rotation of the SPEED control will load the motor down to locked rotor. (Note: In selecting a specific test point for a torque/speed reading it is usually best to set the SPEED control at a point exceeding the test point, then rotate it counterclockwise back to the test point. This helps settle the system and stabilize the test-point value more quickly. Response sluggishness to these adjustments is normal; it is caused by mechanical inertia and electrical delays.)

4.0 X-Y RECORDING: GENERAL INFORMATION

Two outputs appear on the rear panel of the Model 4619 controller, OUTPUT SPEED and OUTPUT TORQUE. The red jack on each is positive(+), the black is negative(-) and ground. When connecting an X-Y recorder to the controller, use either a jumper or shorting bar to connect the recorder ground to either of the controller's black terminals.

Either axis of an X-Y recorder can be assigned to torque and either to speed, depending on scaling and data presentation; X-Y recorders are rarely square.

The analog outputs from the controller are unidirectional and of low impedance. If you wish to reverse the polarity of the input to either recorder axis, simply reverse the axis input connector from the controller.

4.1 ANALOG SPEED OUTPUT The signal amplitude is 10.00 volts at full scale for each position of the SPEED RANGE switch. Therefore the precise output voltage (E_n) for a given speed (RPM) can be calculated from this ratio:

$$E_n = \frac{10 \text{ RPM}}{\text{RANGE}}$$ (Note: RPM always ≤ SPEED RANGE setting.)

Example for 4-pole 60-Hz motor with free-run speed of 1780 RPM, using the 2(000) position on SPEED RANGE:

$$E_n = \frac{10 \times 1780}{2000} = 8.9 \text{ VDC } (\pm 1\%)$$

(Note: Zero RPM will not be absolute zero volts, since up to ±5 millivolts (.05% fullscale) is possible. This value is adjustable; refer to paragraph 13.0.)

4.2 ANALOG TORQUE OUTPUT The analog torque output (E_q) is proportional to the torque reading of the Model 4605 or 4615 readout. The relationship is as follows (DR represents the readout of all digits, whole or decimal, but with the decimal point, if any, omitted):

$$E_q = 4 \times DR \times 10^{-3}$$

Example for digital display of 48.2 oz.ft. of torque:

$$E_q = 4 \times 482 \times 10^{-3} = 1.93 \text{ VDC } (\pm 1\%)$$

As with analog speed output, zero torque is not absolute zero volts. If adjustment is required refer to paragraph 13.0.

5.0 X-Y RECORDING: SETUP AND OPERATION

5.1 Disconnect any test motor or other hardware coupled to the dynamometer shaft.

5.2 Install the calibration beam following the instructions in the dynamometer manual; then using a precision weight establish a torque value within your range of interest.

5.3 Scale the X-Y recorder for the calibration required.

5.4 With the weight removed, check zero. If the zero has moved, reset it and recalibrate.

5.5 Remove the calibration beam and couple a test motor to the dynamometer.

5.6 With the controller SPEED RANGE set higher than the motor free-run speed, start the motor. Scale the speed axis of the X-Y recorder to the desired RPM per inch or centimeter excursion.

5.7 Switch the controller's DYNAMOMETER toggle to ON. The BRAKE ENERGIZED light should be out. Slowly rotate SPEED RANGE VERNIER counterclockwise until the BRAKE ENERGIZED light comes on. Then slowly rotate it clockwise until the light just goes out.

All equipment to record is now set up, and a final, accurate test curve of speed vs. torque can be attempted. But before doing so you should become familiar with the three additional functions that appear on the front panel of the controller: AUTOMATIC SPEED CONTROL, INERTIAL ERROR COMPENSATION, and TEST TIME. They are covered respectively in Sections 6, 7, and 10 following.

6.0 AUTOMATIC SPEED CONTROL

This control operates in the speed-control mode and performs essentially the same function as the manually adjustable SPEED control, but it is smoother operating and automatically repeatable.

6.1 Set the TEST TIME switch to 20 (seconds). This is an average setting; see Section 10 for further information on test times.

6.2 Activate AUTOMATIC SPEED CONTROL by depressing the button to light it up; the light signals activation.

6.3 Set the RPM toggle to DECREASING.

These settings will cause the motor to ramp from free run to locked rotor in approximately 20 seconds. (Note: The AUTOMATIC SPEED CONTROL can be deactivated at any time simply by pressing the button again to put the light out; this will return the motor to free run.)

6.4 At any load point the RPM toggle can be switched up to INCREASING. This reverses the ramp, causing the speed to increase at the same rate as it previously decreased.

6.5 To cancel out the ramp and hold the test point, switch the RPM toggle to its center neutral position.

6.6 There is flexibility in the method of controlling the equipment. For example, the RPM toggle can be left in DECREASING and ramp control initiated solely by the AUTOMATIC SPEED CONTROL button.

7.0 INERTIAL ERROR COMPENSATION: GENERAL INFORMATION AND SETUP

In X-Y recording the motor speed is continually changing. Thus the true torque measurement is the sum of two factors: the actual turning power of the motor, plus the addition (when decelerating) or subtraction (when accelerating) of the stored energy in the system (inertia). The inertia factor is proportional to the rate of change of speed, and the mass of the system.

The INERTIAL ERROR COMPENSATION control supplies an adjustable quantity (≈mass) of the differentiated speed signal (differentiation = rate of change). This electrical value is set up as negative in decelerating and positive in accelerating, and is summed with the unipolar torque signal.

7.1 Release the lock on the side of the control by setting it at its up (1 o'clock) position. Then turn the knob full counterclockwise to bring both rotating bands to zero.

7.2 Set up the equipment as in Section 6. Then establish a torque/speed point manually with either the SPEED or the TORQUE control. When the motor has stabilized and speed is constant, drop the recorder pen to mark this point.

7.3 Return the control full counterclockwise, and using the AUTOMATIC SPEED CONTROL, record a curve around the point obtained manually.

7.4 Return the motor to free run.

7.5 Rotate the control one turn clockwise and repeat the operations in paragraphs 7.2 and 7.3.

7.6 Continue rotating and repeating until the RPM toggle can be switched back and forth from INCREASING to DECREASING while the curve almost retraces itself. At that stage the correct setting has been reached.

7.7 When the correct setting is established, lock it in by setting the lock at its down (2 o'clock) position. The value will be repeatable for future testing if the mass of the system remains approximately the same and the same SPEED RANGE is used.

7.8 Typically, leave a slight lead — perhaps around .5 percent higher torque — on the deceleration curve. The magnetic alignment of the armature to the field is altered upon acceleration or deceleration and in addition it is natural for some rotor heating to occur, resulting in displacement of the retrace curve.

8.0 LOCKED-ROTOR TESTS

To obtain locked-rotor torque as rapidly as possible and with cold-motor performance, the test procedure outlined in Section 6 should be modified as follows:

8.1 Set the DYNAMOMETER ON/OFF switch at ON.

8.2 Set the TORQUE STABILIZED/OPEN LOOP switch at OPEN LOOP.

8.3 Rotate the TORQUE control full clockwise.

8.4 For X-Y data recording, be sure the recorder is on and calibrated, and the pen up.

8.5 Close the circuit breaker to the motor and immediately drop the recorder pen, then raise the pen and open the circuit breaker. This takes approximately two seconds. (Note: Because of magnetic slotting effects and bearing friction, most motors with plain bearings, and to a lesser extent motors with ball bearings, exhibit a range of locked rotor values; typically, a plain bearing is free only when it has rotation to develop an oil film between shaft and bearing. This range of locked-rotor values can be as high as 30 percent, depending on the motor.)

9.0 TORQUE (CONTROL MODE)

This is a manual control, its positions functioning as follows:

9.1 OPEN LOOP With the toggle in this position the TORQUE control regulates current to the dynamometer brake without feedback reference.

9.2 STABILIZED With the toggle in this position the actual torque value is compared with the torque potentiometer setting, and the current to the dynamometer brake is controlled proportional to the difference. Therefore the torque is maintained constant despite any speed changes, temperature changes, or hysteresis effects. (Note: This control is not useful for locked-rotor tests; a torque signal is necessary for closed-loop operation, and if the test motor is not energized there is no torque signal.)

11.0 STABILITY

Generally, the minimum time a motor is under load beyond the maximum-efficiency operating point, the better. But necessary damping and delays in the data signals limit the speed with which data can be obtained while still maintaining accuracy. As a rule of thumb for best results, use a maximum recording time of 1.5 seconds per inch, or .6 seconds per centimeter. This translates to a TEST TIME setting of 15 or higher for most average conditions, with of course other settings for special situations.

10.0 TEST TIME

System damping is controlled by a locking potentiometer on the rear panel of the controller. The potentiometer should not be rotated full counterclockwise, which eliminates the rate feedback signal and results in system instability, or full clockwise, which causes heavy system damping and results in extreme sluggishness. Normally the most desirable position for critical damping is close to center, with acceptable variance from center depending on the motor/dynamometer combination in use. When adjusting, rotate the potentiometer very slowly.

12.0 DESCRIPTION OF AMPLFIERS U11 THROUGH U14

Amplifier U11 is the SPEED control summing amplifier. It receives three inputs to the inverting summing point: speed analog, rate feedback signal, and the controlled reference.

Amplifier U12 operates essentially identically to amplifier U11 except that its signal sources are an analog proportional to torque or brake current as selected by the STABILIZED/OPEN LOOP switch.

Amplifier U13 serves the function of automatic biasing off the preamplifier (and subsequently torque) if there is no speed present on the dynamometer. Automatic biasing is desirable in case the TORQUE control is set for some value when the motor is off and the switch is in its STABILIZED position; in this situation it prevents amplifier U12 from driving the dynamometer brake to full torque.

Amplifier U14 is the rate-feedback device essential for the system's stability. It receives a signal from a 1.0-ohm current-sampling resistor in series with the dynamometer brake. The level of this signal is controlled by the back-panel STABILITY control. The signal is decoupled by a 47MFD tantalum capacitor. Therefore the output is an AC signal in phase, and proportional to the brake current change. It is applied directly to the summing points of amplifiers U11 and U12.

13.0 ZERO ADJUSTMENTS AND SYSTEM BALANCING

Inside the top cover of the controller is a chart identifying various trim pots, their locations, and adjustment procedures. A copy of the chart is shown below.

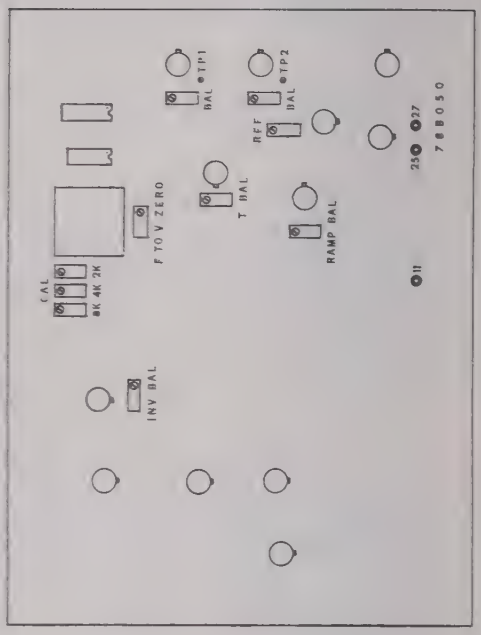
Normally, periodic adjustment and calibration of these various electronic elements is unnecessary since minor alteration in full-scale values and offsets is of no consequence because calibration is performed on the readout recorder each time the equipment is set up.

The following description of the actual function of each of these adjustments is primarily to assist in understanding their purpose and the controller's operation.

Model 4619 Zero Adjustments and Calibration Procedure
(Voltmeter required resolution ± .001 VDC)

STEP:

1. Disconnect the 4-pin torque-input cable from the model 4605 or 4615 readout. Short the cable pins together by wrapping a length of fine wire around all four, being careful not to bend them.
2. Connect the voltmeter between pad 27 and common (chassis) and adjust "Ref" for 5.00 VDC.
3. Connect the voltmeter between TP1 and common and adjust "TP 1 Bal" for best zero. (see note)
4. Repeat Step 3 for TP 2.
   NOTE: An exact zero is unattainable here. Adjust for lowest positive reading where additional adjustment results in a negative output.
5. Connect the voltmeter to the torque output jack and adjust "T Bal" for zero ± .001 volt.
6. Connect the voltmeter to the speed output jack and adjust "F to V Zero" for zero ± .001 volt.
7. Connect the voltmeter between pad 11 and common and adjust "Inv Bal" for zero ± .001 Volt.
8. Connect the voltmeter between pad 25 and common, put the unit in the "automatic speed control" mode and using the "RPM inc.-dec." switch set the output for approximately 1.0 volt. Adjust "Ramp Bal" for lowest drift in output voltage.
9. Connect the voltmeter to the speed output jack. With the "speed range" switch in the 2(000) position and a known shaft speed of between 1000 and 2000 RPM, calculate the output voltage (En) using the equation $En = \frac{10 \text{ (RPM)}}{\text{Range}}$. Adjust "2K cal" for correct En.
10. Repeat Step 9 with the switch in the 4(000) position. Adjust "4K cal" for correct En.
11. Repeat Step 9 with the switch in the 8(000) position. Adjust "8K cal" for correct En. The 16(000) and 32(000) ranges are automatically calibrated.
12. Adjust "stability" control on rear panel for maximum stability @ minimum sluggishness as observed on the XY Recorder. (As a starting point, rotate control full CCW then ¼ turn CW.)



13.1 In step 1 the purpose of shorting the input connector is to establish the torque input at zero potential, thereby allowing the later steps 3,4, and 5. There is no torque signal level calibration.

13.2 A precision reference voltage for speed and torque ranging is necessary. The value is established at 5.00 VDC as determined by the IN821 Zener diode and op-amp U7. This is adjusted in step 2.

13.3 Amplifiers U3 and U4 are to linearize (convert to unipolar) the incoming bipolar torque signal. The zero offset of these amplifiers is affected by steps 3 and 4.

13.4 The true zero of the torque output signal is obtained by the offset balance of U5 and "T BAL", step 5.

13.5 Speed output zero is accomplished by the offset adjustment of "F TO V ZERO," step 6, which balances the frequency to voltage converter module 77M009.

13.6 The analog speed signal processed by the 77M009 must be inverted and filtered for application to the dynamometer brake control circuit. This dual function is accomplished by the U10. The procedure for balancing this amplifier is specified by step 7.

13.7 Step 8 involves balancing the integrator amplifier U9. When the AUTOMATIC SPEED CONTROL switch is activated and the RPM INCREASING-DECREASING switch is in the center position, amplifier U9 is an open integrator. This is an inherently unstable condition and the best that the balance control ("RAMP BAL") can do is to minimize the drift rate.

13.8 Steps 9, 10, and 11 are actual speed calibration procedures to establish the correct full-scale analog speed signal on all ranges. The calibration resistors actually adjust the gain of the F to V converter module so that 2000 Hz = 10V, 4000 Hz = 10V, 8000 Hz = 10V.
The conversion formula: $Rf \text{ (in ohms)} = \frac{2.7 \times 10^6}{\text{frequency in Hz}} \pm 20\%$

14.0 METRIC AND POWER CONVERSIONS

METRIC

millimeters x .03937 = inches
millimeters ÷ 25.4 = inches
grams ÷ 28.35 = ounces
kilograms x 2.2046 = pounds
oz.in. x 72.008 = gr.cm.
oz.ft. x .864093 = kg.cm.
lb.in. x 1.15212 = kg.cm.
kg.m. x 9.80665 = N-m.*
oz.in. x 7.06155 x 10^{-3} = N-m.*

*Newton metre

POWER

oz.in. x rpm(9.921×10^{-7}) = hp
oz.in. x rpm(7.401×10^{-4}) = watts
watts ÷ 746 = hp

For further information or technical assistance, please feel free to contact our Customer Service Department at any time.

MAGTROL LIMITED WARRANTY

This Magtrol product is warranted against defects in materials and workmanship for ninety (90) days from the date of delivery. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Magtrol. Additionally, any repairs which may become necessary beyond the ninety (90) day warranty period will be made subject to review by our quality control department. No other warranty is expressed or implied. We are not liable for consequential damages.

Customer assistance agreements are available for Magtrol products that require maintenance and repair on site.

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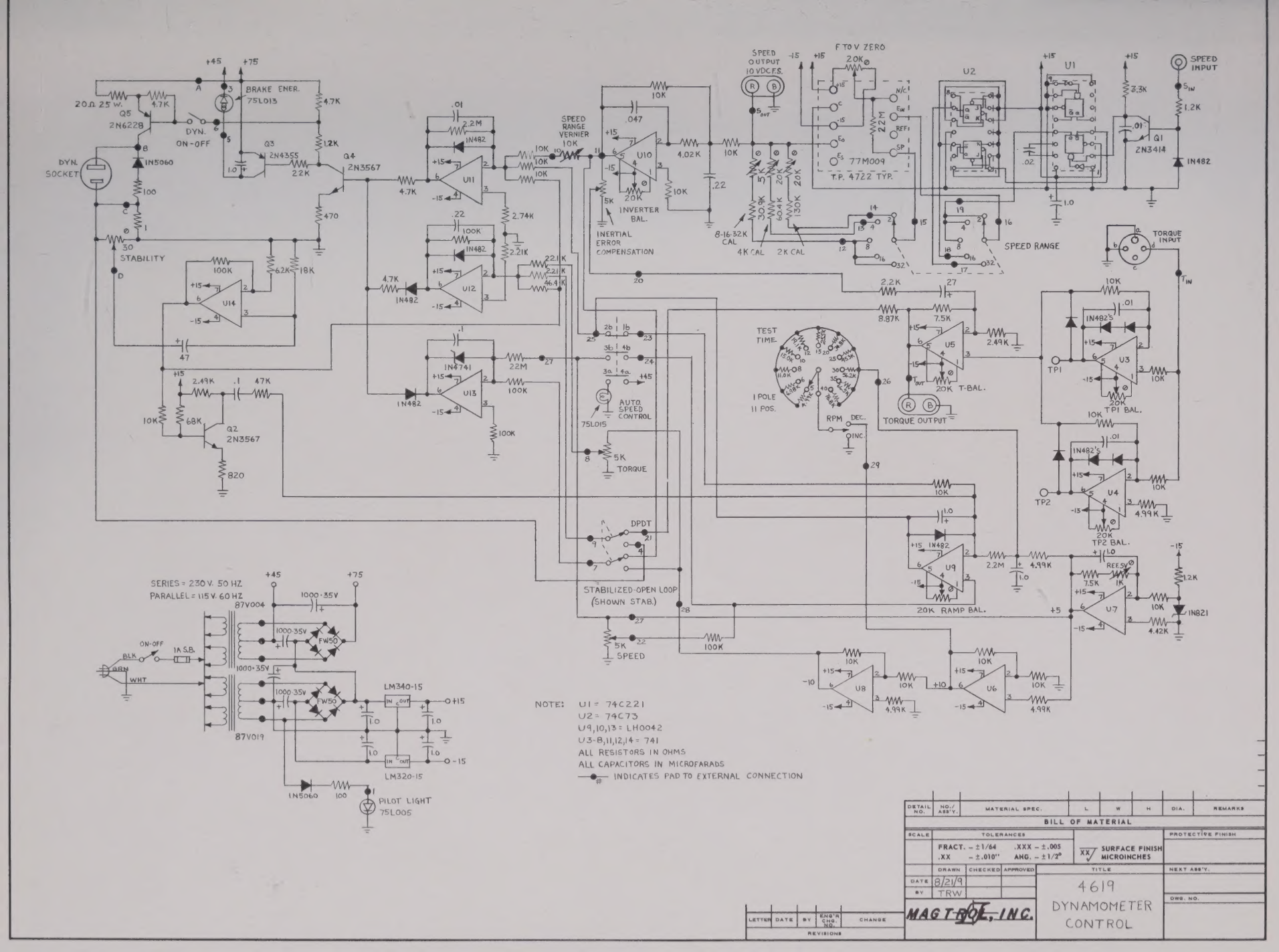

NOTE: U1 = 74C221
U2 = 74C73
U9,10,13 = LH0042
U3-8,11,12,14 = 741
ALL RESISTORS IN OHMS
ALL CAPACITORS IN MICROFARADS
—#— INDICATES PAD TO EXTERNAL CONNECTION

DETAIL NO.	NO./ ASS'Y.	MATERIAL SPEC.	L	W	H	DIA.	REMARKS

BILL OF MATERIAL

SCALE	TOLERANCES		PROTECTIVE FINISH
	FRACT. – ±1/64 .XX – ±.010"	.XXX – ±.005 ANG. – ±1/2°	XX/ SURFACE FINISH MICROINCHES

	DRAWN	CHECKED	APPROVED
DATE	8/21/9		
BY	TRW		

TITLE: 4619 DYNAMOMETER CONTROL

NEXT ASS'Y.

DWG. NO.

MAGTROL, INC.

LETTER	DATE	BY	ENG'R CHG. NO.	CHANGE

REVISIONS

MAGTROL PRECISION DEVICES, EQUIPMENT, AND INSTRUMENTS

FOR TORQUE CONTROL

Hysteresis Brakes and Clutches Hysteresis advantages for the OEM include extra-long life, precise repeatability, environmental stability, temperature insensitivity, broad speed range, operational smoothness, and low power consumption. Use hysteresis brakes and clutches in your product for speed control, tensioning control, load simulation, disc-pack stopping, mechanical damping, limited-rotation slip clutching, antibacklash, and similar torque-control applications.

Friction Brakes and Clutches Miniature, high-precision, available for special needs particularly in aerospace, missile, and computer applications.

FOR MOTOR ANALYSIS

Absorption Dynamometers and Accessory Equipment Magtrol absorption dynamometers incorporate hysteresis brakes, thus providing the hysteresis advantages outlined above. Precise torque control permits testing of motors from no-load to locked rotor or armature. Other dynamometer features include variable load capacity through single-knob control on power supply, and calibration in English or metric. Several models. X-Y programming and plotting available.

Dynamometer accessory equipment includes power supplies, tachometer, torque/speed read-out, and controller.

FOR POWER MEASUREMENT

Multi-Range Digital Analyzer A versatile instrument for testing and certifying electric motors and equipment. Simultaneously displays 2-50 amps, 15-600 volts, and 30-30,000 watts. Error-proof and highly accurate, the Magtrol analyzer offers many features including all electronic circuitry and simple plug-in and pushbutton operation.

* * * * * *

Two informative booklets free on request: *Torque Control with Hysteresis Devices*, and *Hysteresis Brakes for the OEM.*

Literature is available on all Magtrol products. Tell us your interests and we'll be happy to send you appropriate brochures.

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